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# HEAD INJURIES IN MOTOR-CYCLISTS

## THE IMPORTANCE OF THE CRASH HELMET

BY

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During the first twenty-one months of war the number of motor-cyclists and pillion passengers killed on the road was 2,279—21% more than during the corresponding months of peacetime (1,884 killed between September, 1937, and May, 1939). The frequency of head injuries was high (Table I), and in a number of cases the fatal outcome might have been avoided if adequate protection for the head had been worn. But, as will be observed, the issue is not clear-cut, since multiple injuries other than head injuries undoubtedly contributed to death, though to what extent cannot be defined.

The second section of this paper deals with such material as it has been possible to collect relating to non-fatal head injuries to motor-cyclists; the third briefly indicates some of the causes of accidents, and offers suggestions for prevention and for protection to the heads of riders by the general use of crash helmets of a type described. In conclusion, 7 cases, seen by me, are reported of non-fatal injuries to riders wearing crash helmets, and evidence is adduced to show that in most of them graver injuries would have been sustained without such protection.

### Fatal Injuries

Through the kindness of the Royal Society for the Prevention of Accidents and of the Registrar-General it has been possible to procure the particulars and the certified cause of death in a series of 149 fatal accidents occurring among motor-cyclists (excluding pillion passengers) in the last four months of 1940. Table I shows that in 102 of 111, or 92%, of the cases in which the cause of death is specified a head injury occurred. In 85 cases death was ascribed to head injury without mention of other injury, but from additional information obtained as to 10 of these cases, either from case notes or from inquest reports, it becomes clear that, when the head injury dominated the clinical picture, other injuries often were not mentioned in the death certificate. Thus in one case there were, in addition to the head injury, fractures of humerus, fibula, and fingers; in another, fracture of one clavicle; in another, compound fracture of the femur; in two cases, bad burns owing to a petrol fire when two motor-cyclists met in head-on collision. In addition, in one other case, in which the patient was certified as dying from shock following multiple injuries, Dr. Robb-Smith found at necropsy the following injuries: fractures of the anterior and middle cranial fossae, slight subdural haemorrhage, multiple areas of cerebral contusion, fractures of the mandible, maxilla, nasal bones, compound fracture of the right tibia and fibula, and slight laceration and fat embolism of the lungs. In probably two-thirds or more of the 149 fatalities there were multiple injuries of a major character, though head injury was a factor in most of the 149.

TABLE I.—*Certified Cause of Death in* 149 *Cases of Accidents to Motor-cyclists* (149 *Cases*)

| | | |
|---|---|---|
| Head injuries* | | 102 |
| Head injury alone | 85 | |
| „ „ and other unspecified injuries | 11 | |
| „ „ „ fracture of lower limb | 2 | |
| „ „ „ spinal injury | 1 | |
| „ „ „ facial injury | 1 | |
| „ „ „ meningitis | 2 | |
| Multiple unspecified injuries | | 38 |
| Other injuries | | 9 |
| Fractured jaw and pneumonia | 1 | |
| Fracture-dislocation of cervical spine, etc. | 1 | |
| Thoracic injury, with haemorrhage, etc. | 1 | |
| Thoracic and abdominal injury, with haemorrhage | 1 | |
| Abdominal injury, with haemorrhage | 2 | |
| Fractures of limbs | 2 | |
| Multiple fractures of limbs and crushed thorax | 1 | |

In 3 of the above cases gas gangrene was given as a cause of death. In 3 of the cases death occurred under anaesthesia for operation on the injuries.

* The term "head injury" is used to cover the following terms on the death certificate: Fractured skull, contusion of brain, laceration of brain, intracranial or cerebral haemorrhage following injury, oedema of brain due to injury, cerebral compression.

To assert that head injury is the sole cause of death in motor-cycle accidents would be misleading, but there can be little doubt that many patients in this series would have lived if their heads had been adequately protected. It is the combination of injuries, each in itself probably not fatal, that so often produces death, as in the following case.

### Case I: Fatal Injury

A man aged 22 (Serial No. 131) collided in the black-out with a lorry which had pulled out to overtake a car. He was not wearing a crash helmet. He had concussion and a compound depressed fracture of the right frontal region, a fracture-dislocation of the right ankle, and laceration of the adductor muscles of both thighs. This case has already been described in detail elsewhere (Russell, 1941, Case 2), and it is only necessary to give the main points here.

He was unconscious for three-quarters of an hour after the injury. He showed a fairly severe degree of shock, but following a transfusion he improved. He then complained of pain in the right ankle and became very restless; for this it was necessary to give nembutal and later morphine. Twenty hours after the injury he became unconscious again, and remained so until death. Forty-five hours after injury he began to have convulsive seizures, and twelve hours later he died. His pulse rate was never below 140.

Necropsy (Drs. Robb-Smith and Dorothy Russell) showed, in addition to the injuries already described, a long right fronto-parietal fracture extending on to the roof of the right orbit and involving the sphenoidal and ethmoid sinuses, which contained blood. There was also a fracture of the roof of the left orbit. The right frontal lobe showed superficial laceration of its dorsal surface over an area 5 by 2.5 cm., and the overlying dura was torn. In the brain, beneath the laceration, there was a wedge of softening and diffuse haemorrhage up to 2.5 cm. deep, and the anterior half of the right frontal lobe showed slight oedema. There were also a few punctiform haemorrhages

in the convolutions of the left hemisphere. Microscopic examination revealed fat emboli in the cerebral hemispheres and choroid plexuses.

The lungs showed focal haemorrhagic zones, early inhalation pneumonia, and considerable fat embolism. The adductor muscles of the thighs were grossly torn and bruised, with haemorrhage extending up into the retroperitoneal tissues.

In this case the damage to the brain, apart from fat emboli, was almost entirely restricted to the site of impact. There was no contrecoup damage; probably neither head injury nor limb injury was in itself sufficient to cause death. The injuries as a whole caused shock, and there was blood loss from scalp bleeding. Brain damage produced restlessness, which increased the pain from the foot, and this made the patient more restless. Restlessness may have promoted fat embolism of lungs and brain.

The outlook is often far more grave when head injuries are complicated by injuries elsewhere. The pulse tends to be more rapid, pneumonic signs may set in, often as a result of fat embolism (Robb-Smith, 1941; and Rowlands and Wakeley, 1941). Such patients are in a highly critical state and may be made worse by manipulations, such as setting of their fractures. They tend to travel badly in the early stages. This may be one reason for the fairly general belief that patients with head injuries travel badly—an impression not confirmed by observation of uncomplicated head injuries.

These are some of the most difficult accident cases to treat: they require careful resuscitation, much individual attention to wounds, and continuous supervision so that the right time may be chosen for setting the limbs, operating on the head wounds, and so forth. And the patient should be moved as little as possible. It is not surprising that three of the patients in the series were reported as dying under anaesthesia.

If in Case I a crash helmet had been worn the patient's head injury would probably have been less severe and he might not have died. With equal right it could be argued that if his lower limbs had been protected from injury he would not have died. Protection of the lower limbs is obviously more difficult than protection of the head, but the problem deserves further study.

The rarity of thoracic and abdominal injuries in fatal motor-cycle accidents is to be noted (Table I). Spinal injury also appears to be rare, but is easily overlooked in an unconscious patient and also, if not specifically sought, at necropsy.

## Non-fatal Injuries

It is difficult to get a comprehensive picture of the non-fatal accidents in motor-cyclists or to estimate their frequency. They are evidently fairly common, for in a series of 556 blunt head injuries of known cause admitted over a period of fourteen months to a hospital for head injuries, some in the acute stage but many more in the chronic stage, 122, or approximately 22%, were in motor-cyclists. Of the 122 patients 22 had fractures or other major injuries in parts other than the head. These included fractures in various long bones, with a slight predominance in the lower-limb bones, fractures of the mandible, dislocation of the shoulder, and one case of injury to the spinal cord. This material has the disadvantage of being selected, since the hospital is primarily devoted to head injuries. The proportion of cases showing multiple injuries is therefore probably lower than in an unselected series. There are no examples of brachial plexus injury—known to be a serious and not infrequent result of motor-cycle accidents—possibly for the reason that in accidents affecting the brachial plexus the supraclavicular region receives the force of the blow and the head escapes damage.

The site of violence to the head, as indicated by scalp lacerations or by fractures, shows a predominance of frontal injuries (Table II), but no part of the cranium is exempt. There are several cases of fractures of the occipital bone, at times extending into the foramen magnum. The common

TABLE II.—*Site of the Blow in Motor-cyclists' Head Injuries (93 Cases)*

| | | | |
|---|---|---|---|
| Frontal | 52 | Parietal | 17 |
| Temporal | 12 | Occipital | 12 |

injury, however, is a frontal blow, with laceration of the forehead and multiple fractures, linear or depressed, in the underlying bone. Fracture lines often extend to the roof of the orbit and to the frontal and ethmoidal sinuses, and, in the other direction, backwards along the vertex towards the parietal region. There is superficial laceration of the frontal lobes, and usually the dura is torn. Sometimes there is cerebrospinal rhinorrhoea. There is considerable haemorrhage in both orbits, and sometimes damage to an eyeball or to an optic nerve. The olfactory pathways also are not infrequently interrupted.

## Causes and Prevention

Speeding, especially at corners, poor visibility in black-out or fog, skidding, overtaking, convoy duty, sudden gusts of wind from side-streets—these are some of the causes of accident. The fatal accidents have been carefully analysed by the Royal Society for the Prevention of Accidents, and the reader is referred to their *Road Accident Bulletins*, Nos. 10 and 12. No doubt the conclusions drawn from this analysis would be equally applicable to non-fatal accidents.

The most important and effective method of preventing head and other injuries is careful driving. There

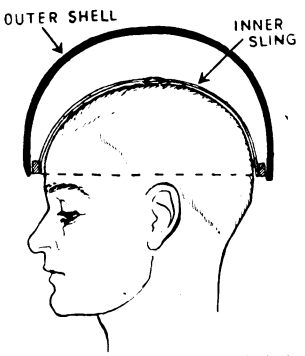


FIG. 1.—Diagram of a crash helmet.

seems to be particular need to impress this obvious fact upon motor-cyclists, since they, more than users of other types of motor vehicle, appear to be exhilarated by their speed and therefore reckless in attaining it. And, unlike occupants of a motor-car, they are not protected by their machine. When motor-cycle accidents occur at high speeds no amount of protection of the head or other parts will prevent gross and often fatal injuries. It is not sufficiently realized that a slight increase in speed may produce a very great increase in the amount of damage.

It is the purpose of this paper to advocate for all motor-cyclists, civilians and fighting Forces alike,* the use of a crash helmet of the type worn by racing motor-cyclists. It consists (Fig. 1) of an outer shell of some firm substance, shaped rather like an inverted pudding-bowl and quite smooth on its outer surface. This is supported by a lining consisting of a series of web slings fitting snugly on the rider's head and attached by its base to the base of the outer shell. The helmet is also retained in place by a chin-

* The requirements of troops under fire are not considered in this paper.

strap. Between the outer shell and the lining there is a gap which may with advantage contain some energy-absorbing material.

### Report of Cases of Non-fatal Injury

So far I have seen only seven cases of motor-cyclists injured while wearing a crash helmet.* In all of them the effects of the head injury had been unusually mild.

### Case II

A rifleman aged 23 (Serial No. 1003) had had a slight head injury, with fifteen minutes' amnesia, two months before his accident during night exercises on June 6, 1941. Riding at 30 m.p.h. he ran into the back of a stationary vehicle. He was

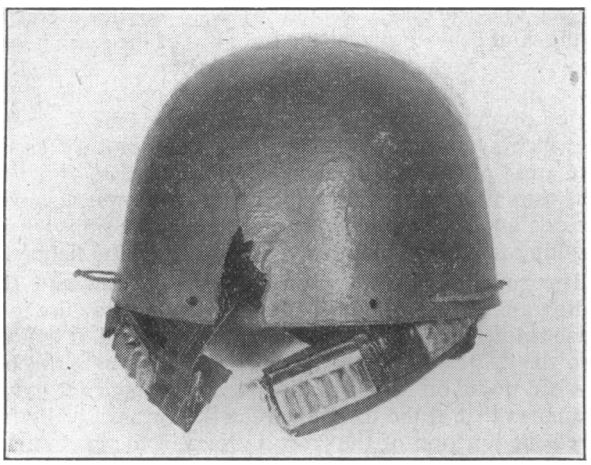

FIG. 2.—Case II. Damage to the outer shell and inner sling of the crash helmet in the right frontal region.

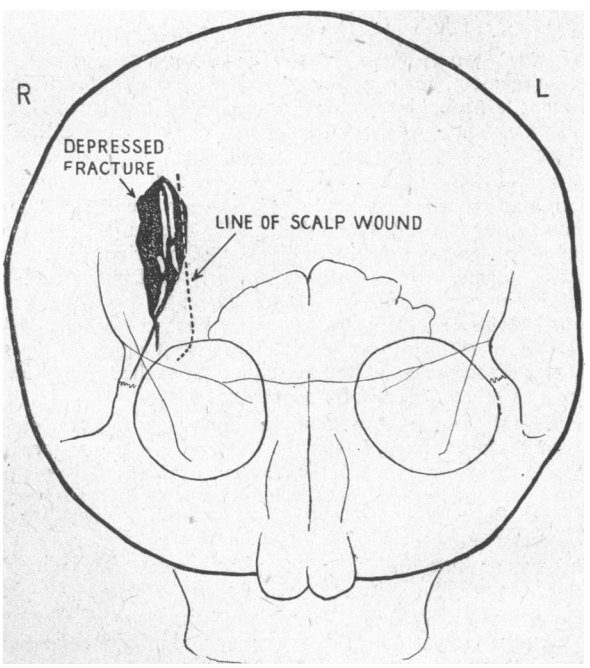


FIG. 3.—Case II. Tracing of radiograph of depressed fracture beneath the site of damage to the crash helmet.

rendered unconscious and sustained a lacerated wound on the right side of his forehead, also a simple transverse fracture of the right tibia and fibula just below their mid-points. His crash helmet was broken in the right frontal region, where part of the outer shell was detached, and beneath this gap the base of the inner sling was broken (Fig. 2). From the upper end of the gap in the outer shell two fissures extended into the rest of the shell, each for a distance of about 2 cm. The gap in the helmet corresponded to the site of scalp laceration. Beneath the scalp wound, but slightly lateral to it, there was a double line of fracture, slightly depressed at one edge (Fig. 3), which extended into the external angular process of the frontal bone.

The duration of his retrograde amnesia was at first uncertain, but two months after the accident he had recovered memory of past events up to within four minutes of the accident. His first memory was of a time forty hours after the accident. During this period of amnesia he had a generalized convulsion, was twice given 1/4 grain of morphine for restlessness, and also had his scalp wound excised and sutured under pentothal anaesthesia.

He was transferred to a military hospital for head injuries on June 12. At that time he was conscious, lucid, and quiet, but he was a little drowsy and showed some defect of memory and concentration and very slight nominal dysphasia. Speech was otherwise normal. He was a left-handed man. He had some stiffness of the neck and very slight papilloedema. There was slight left lower facial weakness. The other cranial nerve functions and motor, sensory, and reflex functions were normal. He was complaining of considerable frontal headache. Lumbar puncture on the eighth day showed a clear colourless fluid under a resting pressure of 90 mm. $H_2O$, containing 0.045% of protein, and 2 lymphocytes and a few red blood cells per c.mm.

Within a few days he became normally alert, his verbal memory became normal, and his papilloedema subsided. His headache persisted unusually long, but finally disappeared after three weeks. The fractured tibia and fibula were treated by manipulation and plaster, and good union was obtained. Return to full duty was delayed by the leg fracture.

This man evidently received a severe blow on the right frontal aspect of his crash helmet, with the production of a scalp wound immediately beneath. Damage to the skull was limited to a fracture beneath the lateral edge of the scalp wound. The appearances suggested that the helmet had struck a slightly concave object which had punched a fairly clean hole in the helmet and had driven the piece of outer shell inwards. Without the crash helmet there is little doubt that a deep penetrating injury would have been produced and that the fracture, like so many of the fractures in unprotected motor-cyclists, would have spread, to involve the frontal and ethmoid sinuses and the roof of the orbit, with considerable displacement of the frontal bone and the eyeball and also laceration of the frontal lobes—an injury, in fact, like that of Case I. As it was, the brain damage was evidently inconsiderable: to judge from the lumbar puncture there was little or no intracranial bleeding, and the evidence of brain damage was limited to slight and fleeting impairment of verbal and other memories. The fact that post-traumatic amnesia lasted forty hours is certainly not a reliable indication of the extent of brain damage, since he received 1/2 grain morphine and intravenous pentothal during that period.

### Case III

A lieutenant aged 23 (Serial No. 582) had a motor-cycle accident while on convoy duty on April 16, 1941. He was overtaking a van, probably at 40 to 50 m.p.h., when it suddenly pulled out to the right and he crashed into it. He had head injuries, a wound five inches long into the left knee-joint, and a transverse fracture of the left patella without displacement, also bruising of the right elbow and left wrist. His crash helmet showed severe injuries on the right side (Fig. 4): the paint was removed in a patchy fashion over a wide area—an indication of the extent of the violence; and there was a T-shaped fracture, with one limb running vertically downwards to the free edge of the helmet above and behind the right ear, and the other passing forwards at right angles to the first almost to the middle line in the frontal region. From the junction of the T, also, a faint crack extended backwards for 2 cm. One of the loops of the inner sling of the helmet was completely torn from its attachments.

* Since this paper was written a further 8 cases have been seen. In all except one there was considerable damage to the crash helmet. All the patients were mildly concussed; one of them had a moderately severe frontal fracture. All made a complete recovery.

On the scalp there was a superficial laceration 1.5 cm. long in the right parietal region, which lay about 1.5 cm. below the junction of the fracture lines in the crash helmet when this was comfortably worn in the usual position. The laceration was evidently produced by indentation of the helmet at the posterior end of its horizontal fracture line. The fact that the two lines did not correspond when the helmet was worn in the usual position gives some idea of the extent to which the helmet was deformed and crushed on to the head at the time of the impact, once the inner sling had broken (Fig. 5). In the skull there

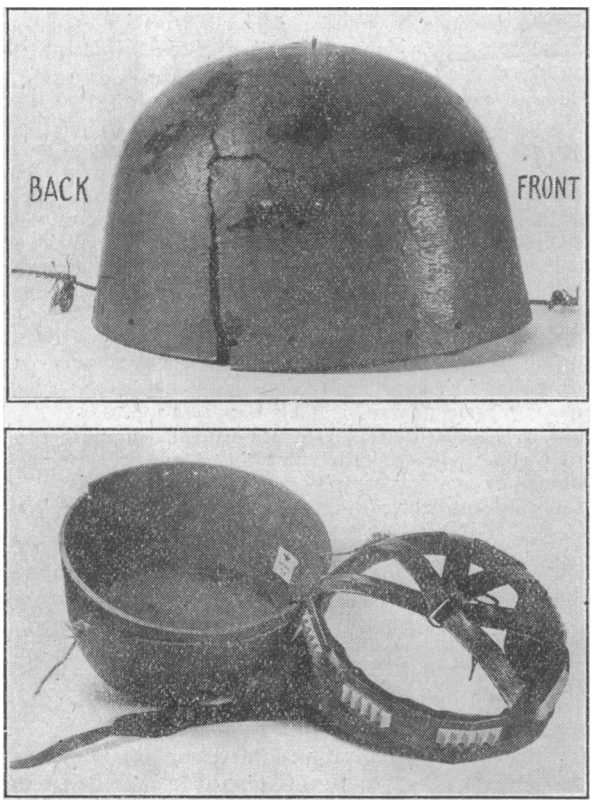


FIG. 4.—Case III. Top: Fracture lines and areas of loss of paint on right side of crash helmet. Bottom: The same helmet showing loss through tearing of one of the loops of the inner sling.

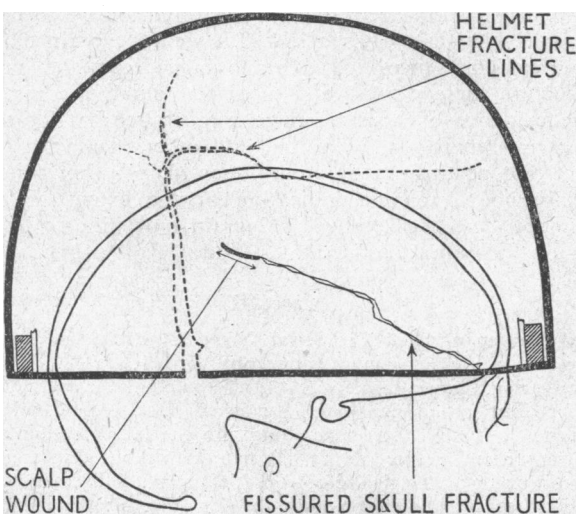


FIG. 5.—Case III. Superimposed diagram of crash helmet and skull, showing lines of fracture in outer shell of helmet, scalp wound, and fissured fracture.

was a fissured fracture about 14 cm. long running forwards and downwards from immediately in front of the site of the scalp laceration almost to the outer angle of the frontal sinus.

The patient was rendered unconscious by the accident. His retrograde amnesia was no more than 1 to 2 seconds, and his first memory after the accident was about two hours later, at which time he was well orientated and showed no neurological signs. For the first few days he could not concentrate and was irritable. For ten days following the accident he had a constant, generalized, dull, throbbing headache, which disappeared a few hours after lumbar puncture (faintly yellow cerebrospinal fluid under a pressure of 140 mm. $H_2O$, and containing 35 mg. of protein per 100 c.cm. and occasional red cells).

His knee wound was treated with sulphanilamide, excision and suture, and fixation in plaster. He walked six weeks after the accident and recovered normal function of his left lower limb six weeks later, at which time he was perfectly well in other ways.

This case illustrates well the value of the crash helmet. A severe blow on the head was partly expended on breaking the crash helmet. It did, however, produce a fracture of the skull beneath one of the fractures of the crash helmet, also a scalp wound. In spite of the fracture of the skull the brain injury was of a minor character, producing a brief period of amnesia and several days of headache, from both of which symptoms rapid and complete recovery ensued. The areas of the helmet denuded of paint (Fig. 4) indicate that the effect of the blow (or series of blows) was widespread, an obvious advantage to the brain and possibly resulting from the smooth round surface of the helmet.

The superimposed diagram of crash helmet and skull radiograph (Fig. 5) shows that the horizontal fracture in the crash helmet is not parallel with that of the skull. It indicates also the degree to which the crash helmet must have been crushed down on to the head by the blow, since it may be presumed that at the time when the skull was actually fractured the junction of the fracture lines in the crash helmet lay approximately over the scalp laceration.

## Case IV

A private aged 26 (Serial No. 914) had an accident on July 27, 1941, when he ran into a car coming out of a side turning. He had no memory of the accident or of the five minutes preceding it, but it is probable that he was travelling at about 25 m.p.h. He had no memory for fifteen minutes after the accident, but his memory of subsequent events was clear.

His motor-cycle was very little damaged. He sustained a small shallow triradiate scalp wound over the right Rolandic region, about 2.5 cm. from the middle line, superficial lacerations above and below the outer part of his right eye (he was wearing goggles, which were very slightly bent but not broken), a subconjunctival haemorrhage on the outer part of the right eyeball, bruising below the left knee, but no fracture of long bones or of skull. From the radiographs it appeared possible that slight separation of the lambdoid suture had occurred, but there was no tenderness of the overlying scalp.

His crash helmet showed no sign of injury in the region of the small scalp wound, but in the left occipital region there was a fissured fracture 7 cm. long extending vertically upwards from an area of the free edge from which the paint had been removed. The helmet was otherwise undamaged. There was no bruising of the scalp beneath the site of this split, and the discrepancy between the site of the right frontal scalp injury and of the left occipital helmet fracture is not explained.

On admission to hospital three-quarters of an hour after the accident the patient was fully conscious and orientated and quite alert. Temperature was 98.4°; pulse rate 80; and mental examination and examination of the central nervous system showed nothing abnormal. The scalp wound was closed with two interrupted stitches. The patient had headache for the first day, but thereafter he was free from symptoms. He got up on the sixth day and was discharged to duty on August 14, 1941.

## Case V

A gunner aged 27 (Serial No. 996), on March 29, 1941, was on his motor-cycle riding slowly in bottom gear from a country lane into a main road. He remembered no more, but was told afterwards that a car ran into him from behind. His crash helmet was not broken, but showed an irregular area of abrasions,

13 by 7 cm., in the left frontal region, and at the postero-medial edge of this area a shallow dent in which the material of the outer shell was softened. In the area of abrasions the varnish was removed and there were numerous curved linear lacerations in the paint running downwards and forwards in parallel lines, and deepest at the antero-lateral margin of the area (Fig. 6). One of the web slings was also torn.

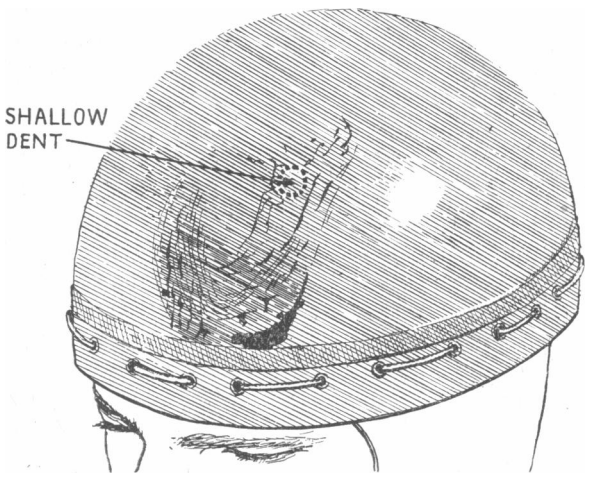


FIG. 6.—Case V.—The effects of a tangential blow on the outer shell of crash helmet.

The patient had no abrasions on the scalp or fracture of the skull. The scalp beneath the site of helmet injury was marked by an area of tenderness which persisted for a few days. As indicated above, there was retrograde amnesia for a few seconds. Post-traumatic amnesia lasted twenty-four to thirty-six hours. He was kept in bed for nineteen days with at first fairly continuous left fronto-parietal headache. Then after only two days out of bed he was returned to his unit, where headaches recurred and he was sent back to hospital. During the next seven weeks he was in two different hospitals and one convalescent depot. At the end of this treatment his headaches were better and he returned to his unit for six days, during which period he had an attack of dizziness. He was returned to hospital, where, after lumbar puncture, he developed intense headache and vomiting. He became depressed and anxious about his own health and that of his wife, who was living in a bombed area and was five months pregnant. He was admitted to a military hospital for head injuries on June 26, 1941.

Inquiries showed that his upbringing had left much to be desired. In peacetime he had had considerable difficulty in getting employment. He enjoyed his life in the Army, but did not mix well with his comrades. He had a horror of bloodshed. Examination showed no abnormality in the central nervous system and only a moderate degree of intelligence. He appeared anxious to succeed at his work, but he was an unstable type of man. He was discharged from hospital on August 18, 1941.

The post-concussional syndrome so well illustrated by this case is a problem entirely different from that with which we are primarily concerned. The case is reported in detail to emphasize the fact that crash helmets cannot be expected to prevent such a syndrome, onset of which does not depend on the severity of the initial head injury, especially in patients of poor mental stamina.

The position of the abrasions on the helmet (Fig. 6) suggests that this patient received a tangential blow, striking first the front part of the helmet to the left of the middle line and proceeding downwards and outwards to the left. This tangential type of injury is on the whole the least harmful type of blow to receive. Dirt-track riders and other experts try to throw themselves clear of the machine at the last moment before the accident. They prefer to volplane to earth and, in so doing, to escape with grazing injuries which are relatively harmless. The longer the body takes to come to rest the less is the force of impact. When the head comes into contact with the ground it is obviously better that the outer shell of the helmet should be abraded than the scalp and skull.

### Case VI

A major aged 29 had a head-on collision with Case VII while on exercises on March 27, 1941. Neither man has any memory of the accident, but probably this patient was travelling at 35 to 40 m.p.h. and Case VII at slightly over 40 m.p.h. Case VII's bicycle was a total wreck, and the front wheel and forks, handlebars, and lamps of Case VI's bicycle were destroyed beyond repair. Both patients were wearing crash helmets.

In this patient the injuries were a small wound in the occipital region one inch in front of the external occipital protuberance, two upper incisor teeth knocked out, a fracture of the upper jaw, cut lower lip, and a compound comminuted fracture of the right patella, and he was unconscious. His crash helmet showed a slight dent in the right fronto-lateral region, and its varnish had been scraped from two areas—one just below the dent and the other in the occipital region. These marks of violence were slight, and it is therefore doubtful whether his head received any severe blow. Radiographs of the skull showed no fracture. His retrograde amnesia was ten to fifteen minutes. His first subsequent memory was three or four days after the accident. During the latter part of this period he wakened readily and responded promptly to questions; he fell asleep easily, was confused and disorientated, and kept asking the same question again and again. For nearly three weeks after the accident he found, when he tried to discuss the affairs of his unit, that his memory was a little hazy. When seen four weeks after the accident he showed no abnormal neurological signs and his intellectual functions and mood were normal. He had suffered twice in earlier years from periods of depression.

Until six weeks after the accident he had recurrent frontal headaches, with occasional pain in the right occipital region and back of the neck. For a further four weeks he remained bedridden on account of his fractured patella. This was treated first by sulphanilamide dressing and plaster, then by secondary suture, and later by excision of the comminuted patella. The final result was a useful limb, with slight limitation of movement at the knee, and return to duty.

It is difficult to estimate the value of the crash helmet in this case. The marks of violence on it were slight, and much of the force to the head and neck appears to have been taken on the face. However, there was a period of unconsciousness or confusion lasting three or four days, and this suggests a fairly severe head injury from violent rotation of the head, or a milder head injury complicated by fat emboli to the brain. There was nothing remarkable about the completeness of the subsequent recovery of intellectual function, though its promptness was unusual.

The position of the superficial scalp cut must be noted. It was a transverse cut an inch long across the middle line one inch in front of the external occipital protuberance. It was within the area protected by the crash helmet. A similar scalp laceration was found in Case IV.

### Case VII

A lieutenant aged 23 met Case VI head-on at a bend in the road. He was wearing a crash helmet. He had no bruises on the head or face, and *x*-ray examination showed no fracture of the skull. He had a compound supracondylar fracture of the right femur and a fracture of the right tibia into the knee-joint, also abrasions on the left lower limb and back. His crash helmet was smeared with blood, but there were no marks of violence on its outer surface; however, the loops of webbing on the interior were in places partly torn from their attachments. He had no memory for a period extending from about ten minutes before to between fifteen and thirty minutes after the accident. On regaining consciousness he was worried because he did not know where he was or how he had hurt himself. He lost consciousness again in the ambulance, but regained it in hospital later in the day, and thereafter was lucid. He had no headache, but was for a time a little nervous at night. He had always been highly strung. When seen four weeks after

the accident he showed no neurological signs or impairment of intellectual function.

His broken leg was treated first by extension in a Thomas splint and then by fixation in plaster. He was discharged from hospital on August 13, 1941, with a useful limb.

This patient, like Cases VI and VIII, was detained in hospital for a long time because of his leg injury, and he could have returned to duty much earlier if it had been only his head injury which required treatment.

### Case VIII

A second lieutenant aged 23 (Serial No. 997) had an accident on June 12, 1941, when he had a head-on collision with an oncoming car. The front wheel of his motor-cycle was buckled and the handle-bars were bent. He sustained a head injury, a double compound fracture of the middle of the shaft of the right femur, a simple butterfly fracture of the right tibia in the lower third, and lacerations of the right knee and right hand. His crash helmet had a little blood on its outer surface, but was otherwise undamaged. There was no sign of injury to the scalp and radiographs of the skull were negative. His retrograde amnesia was one second or less, his post-traumatic amnesia no more than a few minutes. He states that he was lucid after that, but the hospital notes say that he was irrational for the first few days following injury. During that time he complained of headache, though subsequently he denied ever having had any.

When seen eleven days after the accident he was lucid and co-operative and showed no neurological signs or impairment of intellectual function, notwithstanding slight infection of the thigh wound and nocturnal fever. His lower-limb fractures presented a difficult problem of treatment. Extension for the femur was obtained by a Steinmann's pin through the upper end of the tibia, and the tibial fracture was fixed by open operation.

The head injury was obviously very slight in this case, and there is no evidence that the crash helmet in any way decreased its severity.

### Discussion

It is difficult to collect conclusive evidence in favour of crash helmets. No hospital capable of studying this problem receives unselected cases, and it is impossible to judge from any figures available the seriousness of motor-cyclists' head injuries. Some motor-cyclists die on the road. Others are admitted to the nearest hospital and may die within the next two or three days, or, if they recover, may eventually find their way to a central hospital or back to work. Mild cases may never go to hospital at all. Little help can be obtained from central records, since the relevant information is scattered in several different Government Departments.

Though the seven cases reported here cannot be regarded as representative, they constitute, when considered individually, an encouraging experience with crash helmets. In all of them there was concussion. In four cases the damage done to the helmet was considerable: in three (Cases II, III, and IV) the helmet was fractured, and in another (Case V) it bore the marks of a severe tangential blow. In two cases (Cases VI and VII) the damage to the helmet was slight. In Case VIII there was no evidence of damage to the helmet, and it is not impossible that the mild concussion resulted from violence transmitted to the cranium through the spinal column. In the other six cases, however, there is clear evidence of a blow on the head.

In Case II a portion of the helmet appears to have been punched out, and beneath the gap there was a scalp wound and a slightly depressed fracture (Figs. 2 and 3). In Case III the force of the blow was applied over a wide area of the helmet covering the right parieto-frontal region, with the production of an extensive T-shaped fracture in the outer shell (Fig. 4); in addition to a fissured fracture of the skull there was a small scalp wound, from the position of which it was possible to judge to what degree the outer shell of the helmet had been jammed down on to the head at the time of injury (Fig. 5). This extreme displacement of the outer shell could only have occurred when the inner lining of the helmet had given way as a result of one of the slings being torn from its moorings, as shown in Fig. 4. The case illustrates the importance of a strong inner lining.

The crash helmet used in these cases did not invariably prevent fracture of the skull, but it is probable that it did prevent the fracture from spreading as far as it otherwise would have done. In frontal injuries when there is no crash helmet the fracture usually extends back along the roof of the orbit and into the accessory nasal sinuses, whereas in the frontal injury of Case II the fracture was limited to the area of damage of the crash helmet.

The brain damage in all cases was remarkably slight, as judged by the absence of neurological signs and by the promptness and completeness of the recovery of intellectual functions. To be sure, head injuries of similar mildness do occur in motor-cyclists who have not worn crash helmets, but in accidents of the type of Cases II, III, and V the initial neurological disturbance is usually much greater and the recovery slower, though not necessarily less complete.

Theoretically there are certain disadvantages in the crash helmet. It increases the diameter of the head and so the leverage, thus enhancing the possibility of broken neck or rotational acceleration within the cranium. But if the helmet is adequately designed to deaden the blow, then the leverage of the blow is also deadened. Further experience is required to settle these points, and doubtless there is still considerable work to be done in improving the means of diverting the energy of the blow from the brain. It is to be hoped that surgeons will report their observations of head injuries in which crash helmets have been worn.

The frequency of fractures of the lower limb in this series calls for some comment. Five out of the seven patients had severe fractures of the lower limb, four affecting the right lower limb and one on the left side. This series is too small to permit conclusions to be drawn, but Mr. J. C. Scott has kindly supplied me with figures from the Wingfield-Morris Orthopaedic Hospital which suggest that there is a greater tendency to lower-limb fractures, especially compound fractures, in motor-cycle accidents than in other types of accident (Table III). In 10 fatal cases of my series in which full details of the injuries were available, 5 had fractures of the lower limb and 2 had fractures of the upper limb. If by the general use of crash helmets the number of fatalities in motor-cycle accidents is reduced it may be expected that the number of severe fractures of the lower limb requiring prolonged treatment will increase. Their prevention deserves further study.

TABLE III.—*The Relative Frequency of Fractures of the Lower Limb, due to Motor-cycle Accidents, at the Wingfield-Morris Orthopaedic Hospital during Twelve Months from June 1, 1940*

| | Upper Extremity | Lower Extremity |
|---|---|---|
| Motor-cycle accidents .. | 17 (2 compound, 15 simple) | 40 (14 compound, 26 simple) |
| Other causes .. .. | 196 (26 compound, 170 simple) | 220 (24 compound, 196 simple) |

### Summary

In a series of over one hundred fatal accidents to motor-cyclists 92% suffered from head injury and approximately 66% had multiple injuries of a major character.

When non-lethal head injury is combined with other major but non-lethal injuries death may readily occur from cerebral fat embolism and other causes. Alleviation of the head injury by means of a suitable crash helmet may be expected to save life in some cases of this type.

The most effective method of preventing head injuries in motor-cyclists is careful driving. In addition the use of a crash helmet is advocated.

Seven accidents to motor-cyclists wearing crash helmets are reported. In all of them the head injury was mild, though in four there had been considerable damage to the crash helmet.

The incidence of fractures of the lower limb is greater in motor-cycle accidents than in other types of accident, and the number requiring prolonged treatment may be expected to increase when fatalities are averted by the use of a suitable crash helmet.

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# A CASE OF CONGENITAL BILATERAL RENAL HYPOPLASIA

## WITH A SHORT REVIEW OF THE LITERATURE

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Numerous cases of unilateral renal hypoplasia compatible with adult life have been described, but no case of bilateral renal hypoplasia in which the subject survived to adult age seems to have been reported. Indeed, very little mention of the condition has been made by observers in the past. Herbst and Apfelbach (1935), referring to this subject, state:

"Hypoplasia of the kidney was known to Blasius in 1677. Ballowitz (1895) assembled 20 cases, Risel (1903) 36 cases. Since that time many cases have been added to the literature, some of which are definitely hypoplastic, whereas others should be classified as acquired atrophy or one of the other forms of congenital anomaly. . . . According to Papin, hypoplastic kidneys are more frequently found in men than in women, and the right side is more often affected. It has been found in all ages, from the foetus to advanced life. In the living it is always unilateral, since if bilateral it could not sustain life. It may lie in a normal position or may be ectopic. The renal pelvis is usually small and frequently cone-shaped with small calices, some of which may be rudimentary in type."

Marion (1939) stated that congenital hypoplasia of the kidneys can be found on both sides, but he does not dilate further on the condition, merely stating that he had never seen a case.

Eisendrath (1935) has recorded 17 cases of unilateral hypoplasia, and Johnson and Wayman (1936) 8 cases. Eisendrath makes the following points in the diagnosis of the condition:

1. Intravenous pyelography may indicate the extent of the renal parenchyma.

2. Retrograde pyelography may show: (*a*) a triangular or ampullary pelvis, with minor calices arising direct from the pelvis proper without intermediary major calices; (*b*) the presence of only one or two calices arising from a very small pelvis.

3. Cystoscopy is of little value. A rudimentary or occluded ureter may be found.

4. The presence of a small kidney shadow.

In describing the developmental anomalies of the kidneys, of which hypoplasia is one, it is necessary to distinguish carefully between the various conditions which have been described. Mayers (1940), in a classification of renal anomalies, recognizes the following developmental abnormalities:

Congenital Hyperplasia.—Increase in size or number of cellular units—for instance, long kidney, large kidney.

Congenital Hypoplasia.—A macroscopically recognizable kidney—for example, infantile kidney.

Congenital Aplasia.—Hypoplasia to a degree which is not recognizable macroscopically, but of which there is histological evidence.

Congenital Agenesis.—Complete absence of development, therefore no evidence of renal tissue. This may be either bilateral or unilateral (congenital solitary kidney).

A definition of the pathological picture of congenital hypoplasia is given by Johnson and Wayman (1936) as "an abnormally small kidney with fewer glomeruli than normal. These glomeruli are less closely packed together and are often larger than normal."

In connexion with aplasia and agenesis a rigid distinction between these two conditions has not always been made in the literature. Hinman (1940) states that congenital bilateral absence of the kidneys has been recorded 135 times since 1663. He goes on to say that proved bilateral agenesis —i.e., true non-formation rather than secondary atrophy— is even less frequent, for only recently has microscopical examination been carried out to ascertain the presence or absence of atrophied remnants of the metanephros. The majority of these cases of renal agenesis were associated with gross malformations of the other organs.

With regard to the frequency of these conditions, Soloway (1939) states that unilateral renal agenesis is found once in about a thousand necropsies, while bilateral renal agenesis occurs once in about six thousand necropsies. As indicated above, unilateral renal hypoplasia is relatively common, while bilateral renal hypoplasia is, unlike bilateral renal agenesis, almost unknown. The aetiology of these conditions is not known. Hinman (1940) believes that they are all due to developmental arrest, and that the ultimate stage reached (whether agenesis, aplasia, or hypoplasia) is one only of degree. He also admits the rare possibility of an inherent defect in the germ plasm. The following is a report of our case.

### Case History

The patient, a man aged 22, a compositor in civil life, had joined the Army on September 23, 1940. He had always enjoyed good health until his present illness. His mother and father, aged 45 and 50 respectively, are alive and well and have never had any serious illness. There is no family history of any renal disease. The mother is said to have received sanatorium treatment many years ago. There is one sister, aged 20, who had infantile paralysis at 2 years of age, which resulted in weakness in the right leg. There is no history of miscarriages or stillbirths in the family. Both grandfathers of the patient are dead, the cause of death not being known. Both grandmothers are alive and well. The patient has never had rheumatic or scarlet fever; the tonsils were removed during childhood, but there is no record of any renal complications. The patient has never previously suffered from any urinary disturbance such as oliguria or frequency.